# Temporal trends in frequency of dental caries in biocultural context from the prehistoric Georgia bight

Honors Research Thesis

Presented in partial fulfillment of the requirements for graduation with *honors research distinction* in Anthropology in the undergraduate colleges of the Ohio State University

by

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*Key Words*: Bioarchaeology, foragers and farmers, Georgia coast

*Abstract* Along the Georgia coast from the Middle Woodland to the Mississippian period (AD 1 – AD 1500), habitation sites increase in frequency and become denser and more clustered. In addition, it appears that the general pattern is for the site locations to shift towards coastal margins. This study explores the nature of change in the frequency of dental caries, linking trends with shifts in population density and the adoption of maize agriculture. The data set includes counts of carious lesions from a large series of skeletal remains from the Georgia bight. Using comparative statistical analyses including regression models, the data set is examined in order to determine relationships between the frequency of dental caries, settlement, and subsistence shifts in this setting of the American Southeast. This research has the potential to contribute to a broader understanding of the effects of shifts in subsistence and settlement patterns and for drawing inferences about biocultural adaptation in coastal environments.

**Introduction**

The Georgia bight, a large embayment along the Southeastern United States Atlantic coast, is a focal point involving the development of settlements and populations. These in large part have been shaped by changes in subsistence bases and patterns of food consumption which have evolved over time. Before contact with the Spanish in the sixteenth century, coastal and inland populations of the Georgia bight varied in their type of food consumption. This dietary record is revealed through staple isotope analysis conducted by Larsen and colleagues (Larsen et al., 1992; Larsen et al., 2007). Coastal populations consumed more marine foods and less terrestrial foods versus the inland populations (Hutchinson and Larsen, 1998; Reitz, 1988). Then, around the twelfth century, most of the Georgia populations began to incorporate maize into their diet, and this use increased over time with European contact (Hutchinson et al., 1998; Larsen, 1981; Larsen, 1998; Larsen, 2001; Larsen et al., 1992; Larsen et al., 2001; Schoeninger et al., 1990). However, it has been suggested that coastal areas of the American Southeast experienced different levels of influence by maize agriculture as compared to the inland populations (Hutchinson et al., 1998; Larsen, 1981; Larsen, 1982; Larsen et al., 2007; Reitz, 1988). This would affect frequencies of biological stress markers among the populations, based upon the timing and amount of exposure to increased levels of maize consumption.

The purpose of this paper is to test the hypothesis that there is an increase in poorer oral health from Precontact Foraging to Precontact Agriculture. I apply regression models, not previously performed on this data set, in order to provide a more rigorous and precise pattern of oral health for prehistoric Georgia (See Figure 1 and see Larsen, 1982: Chapter 2 for a detailed history of individual sites as well as Larsen et al., 1986). This study builds on Larsen's assessment of oral health in this regional context (e.g. Larsen, 1982; Larsen et al., 2007). A large sample of teeth from the individuals of the populations (Precontact Foraging and Precontact Agriculture) is examined in order to statistically analyze prehistoric Georgia oral health. The expectation is that the main contributing factor to the overall frequency of dental caries will be subsistence base, namely the shift from a diet focused on foraging and hunting to a diet that has added a significant component of detrimental plant carbohydrates.

Dental caries is a disease process involving the formation of lesions where there is the demineralization of dental enamel, as a result of organic acids produced by the fermentation of carbohydrates by bacteria in the human mouth (Larsen, 1999). There are several key factors that play into a tooth being affected by this dental disease: surface exposure of the tooth, bacteria aggregation, and diet (Hillson, 1996; Hutchinson, 2004; Larsen, 1998; Larsen et al., 2001, Kelley and Larsen, 1991).

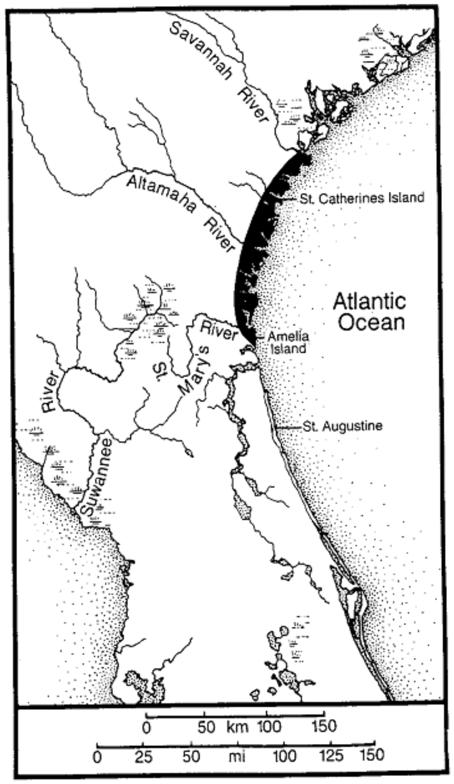



**Figure 1**: The shaded area represents the portion of the coast where the sites are located in this study (figure from Larsen et al., 2007: Chapter 10 in *Advances in Dental Anthropology*).

These bacteria, in particular *Streptococcus mutans* and lactobacilli, transport and process sugars very quickly. As a result of their processing of sugar, acid is a byproduct, and this is produced at a rapid rate (Hillson, 1986; Hillson, 1996; Hutchinson, 2004; Larsen, 1998; Larsen, 2002; Larsen et al., 2001). Due to the byproduct of acid from the result of the processing of sugars by the bacteria, there has been a close association noted between an increase in the frequency of dental caries and an increase in carbohydrate consumption (Hillson, 1996; Hubbe et al., 2012; Larsen, 2002). This is especially reflected in the shift between foraging and agriculture. Most of the evidence for this assertion lies with findings from North America where maize, a carbohydrate, was the primary plant that was being consumed (Larsen, 2002). Dental caries also develops over an individual's lifetime, and the increase of frequency of dental caries tends to have a positive correlation with increase of age among individuals (Hubbe et al., 2012).

Dental caries is most prevalent among molars, due to the high number of fissures, cusps, and pits they possess. These features provide the bacteria with an ideal area to aggregate. The next most susceptible type of teeth is the premolars, and lastly the least susceptible type of teeth is the anterior teeth (incisors and canines) (Calcagno, 1989; Hillson, 1996). Dental caries is rarely seen on the anterior teeth, due to their smooth surfaces (Hillson, 1996).

The sites and associated individuals that were analyzed span three different time periods: the Middle Woodland (AD 1 – AD 500), the Late Woodland (AD 500 – AD 1000), and the Mississippian (AD 800 – AD 1500) (Anderson and Mainfort, 2002; Hutchinson, 2004). In Georgia, between 400 BC to AD 1000, there was a focus on marine resources, and it was not until around the twelfth century or so that there was an increase in maize consumption (Hutchinson and Larsen, 1998; Larsen et al., 1992; Thompson and Turck, 2009). With this shift in subsistence, settlement patterns along the Georgia coast shifted from site frequencies that were lower and more dispersed to site frequencies that were higher, denser, and more focused along the coast (Anderson and Mainfort, 2002; Hutchinson et al., 1998; Thompson and Turck, 2009).

**Materials**

For this study, a portion of a large collection of dental data from skeletal remains was used that comes from the studies of Clark Spencer Larsen (Larsen, 1982; Larsen et al., 2001; Larsen et al. 2007). The teeth were divided into two groups: Precontact Foraging and Precontact Agriculture. The Precontact Foraging group includes 265 individuals from 13 mortuary sites dating ca 400 BC to AD 1300, and the Precontact Agriculture group includes 380 individuals from 14 mortuary sites dating ca AD 1150 to AD 1550 (Larsen, 1982). The sites, individual counts, and collection locations are listed in Table 1 (Precontact Foraging) and Table 2 (Precontact Agriculture). The individual count was based on the given burial and individual numbers listed from Larsen's work (Larsen, 1982; Larsen et al. 2001; Larsen et al., 2007). The teeth and frequencies of dental caries used in the analyses are given in Table 3 (Precontact Foraging) and Table 4 (Precontact Agriculture).

**Methods**

Previous studies focused on chi-square analyses, while this study focused on the use of Probit and Poisson regression. Frequency tables were calculated containing the upper and lower dentition of the individuals for Precontact Foraging and Precontact Agriculture, in order to compare the frequency of dental caries for subsistence bases and sex (See Tables 3 and 4). Chi-square analyses were conducted on teeth that most shared values for both subsistence base groups and sex, which were the UM2 and LM3. However, the focus of the statistics was performing more robust analyses (Probit and Poisson regression) on the dataset to interpret patterns of oral health over time based on the frequency of dental caries.

*Probit Regression*

Probit regression works and provides answers very similar to logistic regression models (such as Poisson regression), but uses a normal distribution to obtain a z-score. Probit models analyze data that are dichotomous or binary in nature. Using the z-score, the results are modeled linearly and probits provide a unit of probability rather than a point as with logistic regression (SAS Data Analysis Examples: Probit Regression, 2013).

*Poisson Regression*

Poisson regression is part of the *generalized linear model family*. This particular group of analyses allows for results of data sets that are binary, count, and success variable. Poisson regression was used in this study, since the data is count data. This means the data reflects "the number of occurrences of a behavior in a fixed period of time" (Coxe et al., 2009). Due to this, age had to be used as an offset since it is not a number of an occurrence of a behavior in a fixed period of time. By putting age as an offset, this took the natural log of the duration of the interval of the measurement so that it could be analyzed in this type of model. The variables being analyzed (dental caries) are count variables, and so they take on a discrete value such as a 0, 1, or 2. This value can only be zero or a positive value, since an event (obtaining dental caries) cannot happen a negative amount of times. This makes Poisson regression better to use for this type of data than a normal distribution. The observed scores of the data are count, and the predicted scores of the data are the natural logarithms of those counts. However, the data being analyzed could have too much variability, which means that standard Poisson regression cannot accurately represent the data. This is known as overdispersion (Cox et al., 2009).

*Overdispersion*

Overdispersion happens when the response variance is higher than the mean or predicted value, so if the dispersion is greater than zero the response variable is then considered over-dispersed (Coxe et al., 2009; Hilbe, 2007; SAS Annotated Output: Negative Binomial Regression, 2013). Overdispersion can be caused by violations of the distributional assumptions of the data. For example, if the data is clustered together, this would violate the likelihood independence of observations assumption (Hilbe, 2007). This causes problems, since it can lead to variables being considered significant when they are actually not or it can lead to their significance being over-estimated (Coxe et al., 2009; Hilbe, 2007). The lower molar data used in this analysis was overdispersed, which can be attributed to population heterogeneity such as differences in diet among individuals or certain individuals being more resistant to dental caries than others. Due to the overdispersion, standard Poisson regression would not work for analyzing the lower molars. Instead, zero-inflated Poisson regression was used.

**Table 1. Site Samples and Time Periods for Precontact Foraging Populations**

| Precontact Foraging (Preagricultural) | | | |
|---|---|---|---|
| Site Name | N | Time Period | Dates |
| Evelyn Plantation | 3 | Middle Woodland | 400 BC - 500 AD |
| Airport Site | 50 | Late Woodland | 500 AD - 1000 AD |
| Deptford Site | 46 | Late Woodland | 500 AD - 1000 AD |
| Walthour Site | 2 | Late Woodland | 500 AD - 1000 AD |
| Cedar Grove Mound A | 1 | Late Woodland/Mississippian | 500 AD - 1150 AD |
| Cedar Grove Mound B | 2 | Late Woodland/Mississippian | 500 AD - 1150 AD |
| Cedar Grove Mound C | 8 | Late Woodland/Mississippian | 500 AD - 1150 AD |
| Cannons Point Site | 18 | Late Woodland/Mississippian | 1000 AD - 1150 AD |
| Charlie King Mound | 13 | Late Woodland/Mississippian | 1000 AD - 1150 AD |
| Johns Mound | 56 | Late Woodland/Mississippian | 1000 AD - 1150 AD |
| Marys Mound | 5 | Late Woodland/Mississippian | 1000 AD - 1150 AD |
| Sea Island Mound | 31 | Late Woodland/Mississippian | 1000 AD - 1150 AD |
| Southend Mound II | 30 | Late Woodland/Mississippian | 1000 AD - 1300 AD |
| | | | |
| Total | *265 | | |

**N = Number of individuals**

***Some of these individuals were removed from the analyses, since some young individuals had teeth present that should not be present given their age.**

**Table 2. Site Samples and Time Periods for Precontact Agriculture Populations**

| Precontact Agriculture | | | |
|---|---|---|---|
| Site Name | N | Time Period | Dates |
| Deptford Mound | 5 | Mississippian | 1150 AD - 1300 AD |
| Lewis Creek Mound II | 8 | Mississippian | 1150 AD - 1300 AD |
| Lewis Creek Mound III | 10 | Mississippian | 1150 AD - 1300 AD |
| Lewis Creek Misc. | 5 | Mississippian | 1150 AD - 1300 AD |
| Norman Mound | 27 | Mississippian | 1150 AD - 1300 AD |
| Oatland Mound | 4 | Mississippian | 1150 AD - 1300 AD |
| Irene Mound Site | 264 | Mississippian | 1150 AD - 1550 AD |
| Low Mound, Shell Bluff (Burial 14) | 1 | Mississippian | 1150 AD - 1550 AD |
| Seven Mile Bend Site | 19 | Mississippian | 1150 AD - 1550 AD |
| Townsend Mound | 2 | Mississippian | 1150 AD - 1550 AD |
| Kent Mound | 25 | Mississippian | 1300 AD - 1550 AD |
| North End Mound (Creighton Island) - Skull X | 1 | Mississippian | 1300 AD - 1550 AD |
| Red Knoll Site | 5 | Mississippian | 1300 AD - 1550 AD |
| Southend Mound I | 4 | Mississippian | 1300 AD - 1550 AD |
| | | | |
| Total | *380 | | |

**N = Number of individuals**

***Some of these individuals were removed from the analyses, since some young individuals had teeth present that should not be present given their age.**

**Table 3. Dental Caries for Precontact Foraging Populations**

| Precontact Foraging | Female | | | Male | | | Indeterminate | | |
|---|---|---|---|---|---|---|---|---|---|
| | $N_T$ | $N_C$ | % | $N_T$ | $N_C$ | % | $N_T$ | $N_C$ | % |
| UM1 | 43 | 0 | 0 | 26 | 0 | 0 | 29 | 0 | 0 |
| UM2 | 36 | 1 | 2.8 | 20 | 0 | 0 | 20 | 0 | 0 |
| UM3 | 34 | 1 | 2.9 | 11 | 0 | 0 | 24 | 0 | 0 |
| LM1 | 54 | 1 | 1.8 | 48 | 0 | 0 | 27 | 1 | 3.7 |
| LM2 | 57 | 0 | 0 | 39 | 2 | 5.1 | 27 | 1 | 3.7 |
| LM3 | 49 | 1 | 2.0 | 26 | 0 | 0 | 28 | 0 | 0 |
| UP3 | 40 | 0 | 0 | 21 | 0 | 0 | 26 | 0 | 0 |
| UP4 | 39 | 0 | 0 | 16 | 0 | 0 | 27 | 0 | 0 |
| LP3 | 49 | 0 | 0 | 31 | 0 | 0 | 29 | 0 | 0 |
| LP4 | 50 | 0 | 0 | 31 | 0 | 0 | 29 | 0 | 0 |
| UI1 | 30 | 0 | 0 | 14 | 0 | 0 | 24 | 0 | 0 |
| UI2 | 25 | 0 | 0 | 15 | 0 | 0 | 25 | 0 | 0 |
| LI1 | 26 | 0 | 0 | 16 | 0 | 0 | 9 | 0 | 0 |
| LI2 | 32 | 0 | 0 | 24 | 0 | 0 | 17 | 0 | 0 |
| UC | 36 | 0 | 0 | 19 | 0 | 0 | 25 | 0 | 0 |
| LC | 45 | 0 | 0 | 28 | 0 | 0 | 27 | 0 | 0 |

$N_T$ **= Number of teeth,** $N_C$ **= Dental caries count, % = Percentage of carious teeth**

## Table 4. Dental Caries for Precontact Agriculture Populations

| Precontact Agriculture | Female | | | Male | | | Indeterminate | | |
|---|---|---|---|---|---|---|---|---|---|
| | $N_T$ | $N_C$ | % | $N_T$ | $N_C$ | % | $N_T$ | $N_C$ | % |
| UM1 | 103 | 17 | 16.7 | 82 | 2 | 2.4 | 65 | 10 | 15.3 |
| UM2 | 94 | 15 | 16.0 | 59 | 3 | 5.1 | 70 | 6 | 8.6 |
| UM3 | 69 | 12 | 17.4 | 24 | 5 | 20.8 | 60 | 9 | 15.0 |
| LM1 | 100 | 25 | 25.0 | 71 | 16 | 22.5 | 69 | 14 | 20.3 |
| LM2 | 87 | 26 | 29.9 | 50 | 18 | 36.0 | 67 | 8 | 11.9 |
| LM3 | 75 | 22 | 29.3 | 32 | 3 | 9.4 | 62 | 15 | 24.2 |
| UP3 | 94 | 12 | 12.8 | 63 | 0 | 0 | 58 | 12 | 20.7 |
| UP4 | 101 | 9 | 8.9 | 41 | 4 | 9.8 | 69 | 5 | 7.2 |
| LP3 | 106 | 3 | 8.8 | 63 | 1 | 1.6 | 73 | 3 | 4.1 |
| LP4 | 110 | 10 | 9.1 | 51 | 3 | 5.9 | 70 | 5 | 7.1 |
| UI1 | 53 | 1 | 1.9 | 32 | 1 | 3.1 | 43 | 0 | 0 |
| UI2 | 40 | 2 | 5.0 | 35 | 1 | 2.9 | 35 | 1 | 2.9 |
| LI1 | 54 | 0 | 0 | 34 | 0 | 0 | 52 | 0 | 0 |
| LI2 | 77 | 2 | 2.6 | 53 | 1 | 1.9 | 62 | 0 | 0 |
| UC | 90 | 9 | 10.0 | 53 | 2 | 3.8 | 64 | 3 | 4.7 |
| LC | 87 | 3 | 3.4 | 59 | 0 | 0 | 68 | 1 | 1.5 |

$N_T$ **= Number of teeth,** $N_C$ **= Dental caries count, % = Percentage of carious teeth**

*Zero-Inflated Poisson Regression*

Count-type data tends to be right-skewed, so there are usually a large amount of low values. Sometimes, though, there are even more low values than would be normally expected in the distribution. In this case, a zero-inflated Poisson model can be used to deal with the excess number of zeros (Coxe et al., 2009; SAS Annotated Output: Zero-Inflated Poisson Regression, 2013). That was the case for the lower molars in this study.

## Results

*Frequencies*

From the frequency tables for Precontact Foraging and Precontact Agriculture, it is clear that there was an increase in the frequency of dental caries for the Precontact Agriculture group in comparison to the Precontact Foraging group (See Tables 3 and 4). This includes an overall increase in dental caries for both males and females. Based on the chi-square tests of the UM2 and LM3 teeth, there are no statistically significant differences (See Table 5).

**Table 5. Chi-Square Analysis for UM2 and LM3**

**Precontact Foraging**

| UM2 | | | |
|---|---|---|---|
| | Male | Female | Total |
| $N_C$ | 0 | 1 | 3 |
| $N_T$ | 20 | 35 | 55 |
| Total | 20 | 36 | 56 |
| | | $X^2 = 1.76$ | |
| | | p = >0.05 | |

| LM3 | | | |
|---|---|---|---|
| | Male | Female | Total |
| $N_C$ | 0 | 1 | 1 |
| $N_T$ | 26 | 49 | 75 |
| Total | 26 | 50 | 76 |
| | | $X^2 = 0.52$ | |
| | | p = >0.05 | |

**Precontact Agriculture**

| UM2 | | | |
|---|---|---|---|
| | Male | Female | Total |
| $N_C$ | 3 | 15 | 18 |
| $N_T$ | 59 | 94 | 153 |
| Total | 62 | 109 | 171 |
| | | $X^2 = 3.34$ | |
| | | $0.10 > p > 0.05$ | |

| LM3 | | | |
|---|---|---|---|
| | Male | Female | Total |
| $N_C$ | 3 | 22 | 25 |
| $N_T$ | 32 | 75 | 107 |
| Total | 35 | 97 | 132 |
| | | $X^2 = 3.33$ | |
| | | $0.10 > p > 0.05$ | |

**Precontact Foraging and Precontact Agriculture**

| UM2 PF vs PA | | | |
|---|---|---|---|
| | $N_C$ | $N_T$ | Total |
| PA | 3 | 59 | 62 |
| PF | 0 | 20 | 20 |
| Total | 3 | 79 | 82 |
| | | $X^2 = 1.00$ | |
| | | $p = > 0.05$ | |

| LM3 PF vs PA | | | |
|---|---|---|---|
| | $N_C$ | $N_T$ | Total |
| PA | 15 | 94 | 109 |
| PF | 1 | 35 | 36 |
| Total | 16 | 129 | 145 |
| | | $X^2 = 3.32$ | |
| | | $0.10 > p > 0.05$ | |

**$N_T$ = Number of teeth, $N_C$ = Dental caries count, PA = Precontact Agriculture, PF = Precontact Foraging, $X^2$ = chi-square value, p significance is standard < 0.05**

*Probit Regression*

The upper right and lower right molars were analyzed using Probit regression and only the URM1 from the Precontact Agriculture group was found to have statistical significance:

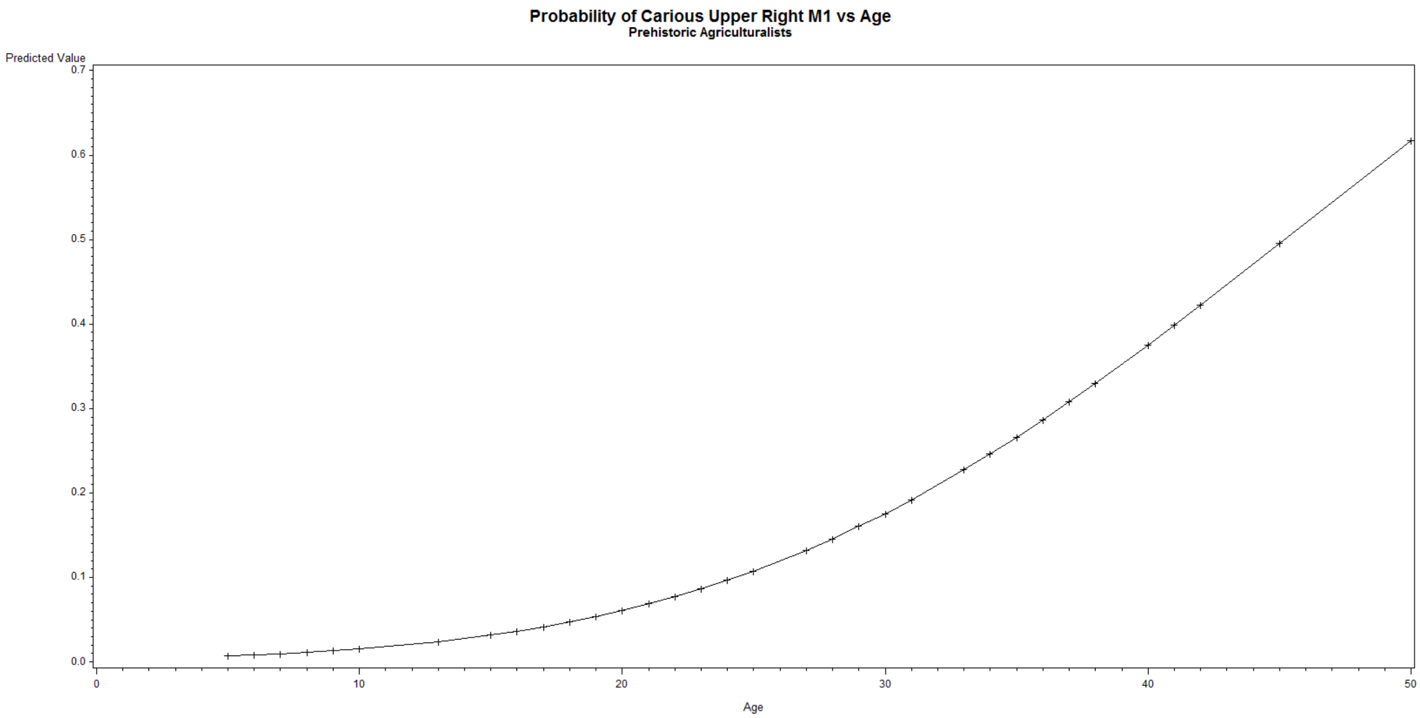
Age: URM1 = -2.7747 + 0.0614 (age) $X^2 = 10.87$, $p = 0.001$

Sex: URM1 = -1.9907 + 0.987 (sex) $X^2 = 4.57$, $p = .0326$

Sex and Age: URM1 = -2.9582 + 0.4446 (sex) + 0.0551 (age)
Sex: $X^2 = 0.76$, $p = 0.3848$ Age: $X^2 = 7.21$, $p = 0.0072$

The results demonstrated that as age increased the rate of dental caries increased. For each year, the Z-score increased by 0.0614, so a 10 year old had a probability of 1.5% for obtaining a carious lesion, a 30 year old had a probability of 17.6%, a 50 year old had a probability of 39.0%, and so forth (See Figure 2). The Precontact Foraging group contained too few dental caries to add to the regression model.

**Figure 2. Graph of probability of carious upper right molar 1 versus age for Precontact Agriculturalists**




*Upper Molars Poisson Regression*

Precontact Agriculture was found to have a much higher rate of dental caries than Precontact Foraging. To help provide a large enough sample base for statistical analyses, the indeterminate individuals were randomly assigned sex. Precontact Foraging contained too few dental caries to add to the regression model (See Tables 6 and 7). For Precontact Agriculture, the distribution of the carious teeth was not over-dispersed, and standard Poisson regression could be used (See Table 8 and Figure 3). With taking age into account, females experienced a greater frequency of dental caries than males. The females' rate of increase for obtaining dental caries was about 25 times that of the males' rate (See Figure 5) with the equations resulting in:

$$\text{Rate} = -4.1207 - 1.5301\,(\text{sex}) + \ln(\text{age})$$

$$X^2 = 6.69,\ p = 0.0097$$

Male = 0.0162 Female = 0.2327
Female > Male

*Lower Molars Poisson Regression*

As with the upper molars, Precontact Agriculture was found to have a much higher rate of dental caries than Precontact Foraging. To help provide a large enough sample base for statistical analyses, the indeterminate individuals were randomly assigned sex. Precontact Foraging contained too few dental caries to add to the regression model (See Tables 6 and 7). For Precontact Agriculture, the distribution of the carious teeth was over-dispersed, and standard Poisson regression could not be used, so zero inflated Poisson regression was used, which accounted for most of the overdispersion (See Table 8 and Figure 4). This overdispersion can be contributed to population heterogeneity, such as exposed/unexposed individuals or resistant/un-resistant individuals, but this cannot be determined from this analysis. With taking age into account, females again experienced a greater frequency of dental caries than males. The females' rate of increase for obtaining dental caries was about 7 times that of the males' rate (See Figure 6) with the equations resulting in:

$$\ln(u/t) = -3.6736 - 2.0185\,(\text{sex})$$
$$(u/t) = 0.0254 + 0.1583\,(\text{sex})$$

Male = 0.0254 Female = 0.1583
Female > Male

$$X^2 = 4.43,\ p = 0.00353$$

Zero-inflated parameters: $\ln(u/t) = -1.0307 - 21.5871\ (\text{sex})$

$$X^2 = 0,\ p = 0.999$$

**Table 6. Frequency (%) of carious teeth for upper molars for Precontact Foraging and Precontact Agriculture**

**Upper Molars**

| Sex | PA | | | PF | | | |
|---|---|---|---|---|---|---|---|
| $N_c$ | Female | Male | Total | Female | Male | Total | Total |
| 0 | 42 | 16 | 58 | 24 | 13 | 37 | 95 |
| 1 | 4 | 6 | 10 | 0 | 0 | 0 | 10 |
| 2 | 0 | 2 | 2 | 0 | 0 | 0 | 2 |
| Total | 46 | 24 | 70 | 24 | 13 | 37 | 107 |
| | | | | | | | |
| % | 8.7% | 33.3% | | 2.9% | 0% | | |
| Total % | 17.1% | | | 2.0% | | | |

| Age and Sex | PA | | | PF | | | |
|---|---|---|---|---|---|---|---|
| $N_c$ | Female | Male | Total | Female | Male | Total | Total |
| 0 | 42 | 16 | 58 | 24 | 13 | 37 | 95 |
| 1 | 4 | 6 | 10 | 0 | 0 | 0 | 10 |
| 2 | 0 | 2 | 2 | 0 | 0 | 0 | 2 |
| Total | 46 | 24 | 70 | 24 | 13 | 37 | 107 |
| | | | | | | | |
| % | 8.7% | 33.3% | | 0% | 0% | | |
| Total % | 17.1% | | | 0% | | | |

**$N_c$ = Dental caries count, PA = Precontact Agriculture, PF = Precontact Foraging, % = Percent of individuals with dental caries, Total % = Percent of both male and females with dental caries**

**Table 7. Frequency (%) of carious teeth for lower molars for Precontact Foraging and Precontact Agriculture**

**Lower Molars**

| Sex | PA | | | | PF | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $N_c$ | Female | Male | Total | | Female | Male | Total | | Total |
| 0 | 38 | 19 | 57 | | 28 | 21 | 49 | | 106 |
| 1 | 4 | 3 | 7 | | 0 | 0 | 0 | | 7 |
| 2 | 1 | 4 | 5 | | 0 | 0 | 0 | | 5 |
| 4 | 1 | 0 | 1 | | 0 | 0 | 0 | | 1 |
| Total | 44 | 26 | 70 | | 28 | 21 | 51 | | 121 |
| | | | | | | | | | |
| % | 13.6% | 26.9% | | | 0% | 0% | | | |
| Total % | 18.6% | | | | 0% | | | | |

| Age and Sex | PA | | | | PF | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $N_c$ | Female | Male | Total | | Female | Male | Total | | Total |
| 0 | 38 | 19 | 57 | | 33 | 16 | 49 | | 106 |
| 1 | 4 | 3 | 7 | | 0 | 0 | 0 | | 7 |
| 2 | 1 | 4 | 5 | | 0 | 0 | 0 | | 5 |
| 4 | 1 | 0 | 1 | | 0 | 0 | 0 | | 1 |
| Total | 44 | 26 | 70 | | 33 | 16 | 49 | | 119 |
| | | | | | | | | | |
| % | 13.6% | 26.9% | | | 0% | 0% | | | |
| Total % | 18.6% | | | | 0% | | | | |

**$N_c$ = Dental caries count, PA = Precontact Agriculture, PF = Precontact Foraging, % = Percent of individuals with dental caries, Total % = Percent of both male and females with dental caries**

**Table 8. Expected number of dental caries for upper molars and lower molars for Precontact Agriculture**

**Upper Molars**

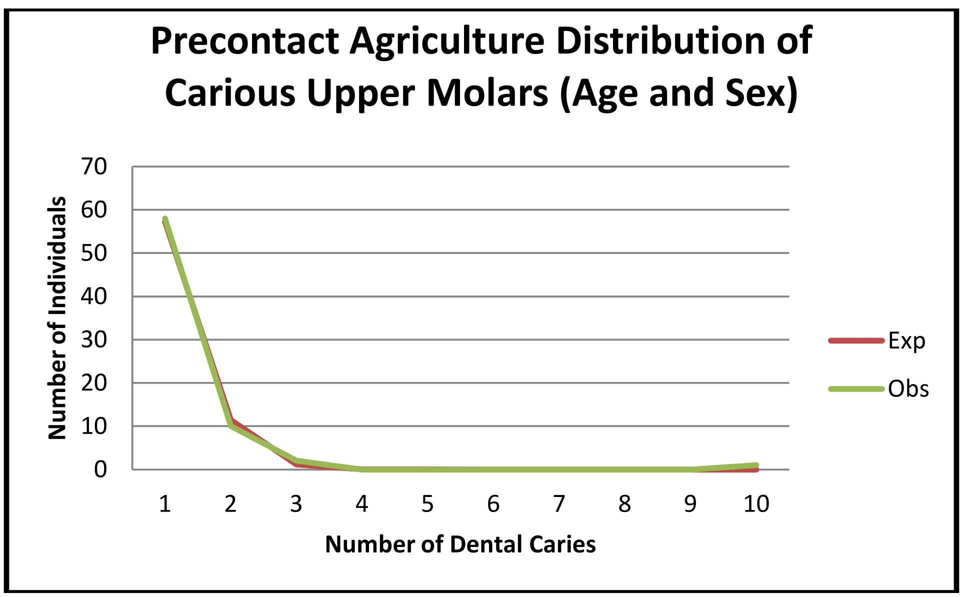
| Age and Sex | PA | |
|---|---|---|
| Y | Exp | Obs |
| 0 | 57.31 | 58 |
| 1 | 11.46 | 10 |
| 2 | 1.15 | 2 |
| 3 | 0.076 | 0 |
| 4 | 0.004 | 0 |
| 5 | 0.002 | 0 |
| 6 | 0 | 0 |
| 7 | 0 | 0 |
| 8 | 0 | 0 |
| 9 | 0 | 1 |

**Lower Molars**

| Age and Sex | PA | | |
|---|---|---|---|
| Y | Exp | Obs | ZIP |
| 0 | 54.89 | 57 | 57 |
| 1 | 13.35 | 7 | 7.34 |
| 2 | 1.62 | 5 | 3.85 |
| 3 | 0.1316 | 0 | 1.34 |
| 4 | 0.008 | 1 | 0.35 |
| 5 | 0.0004 | 0 | 0.07 |
| 6 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 |

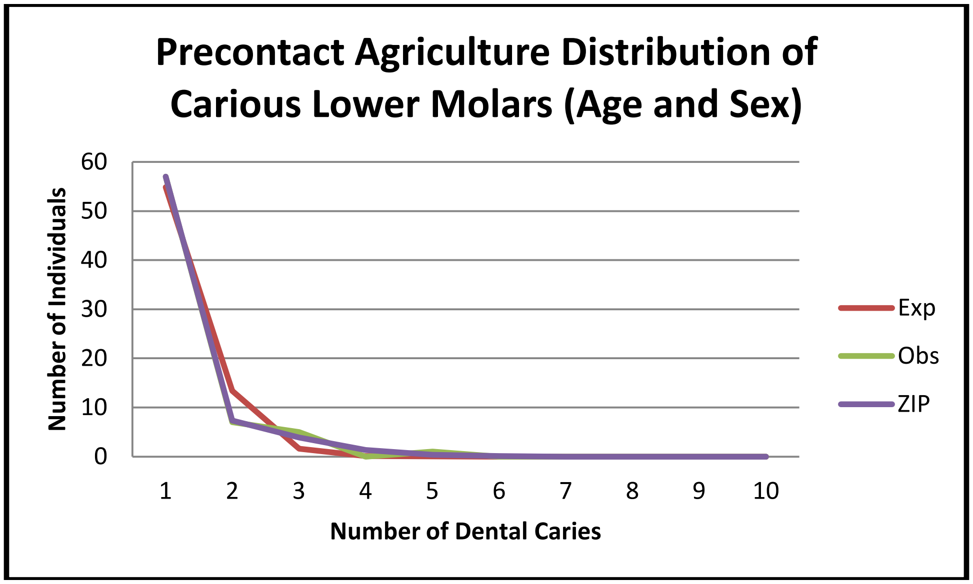
**PA = Precontact Agriculture, Y = number of dental caries, Exp = Expected, Obs = Observed, ZIP = Zero-inflated Poisson**

**Figure 3. Distribution of Carious Upper Molars for Precontact Agriculture Group**




**Exp = Expected, Obs = Observed**

**Figure 4. Distribution of Carious Lower Molars for Precontact Agriculture Group**




**Exp = Expected, Obs = Observed, ZIP = Zero-inflated Poisson**

**Figure 5. Average Time to obtain carious lesions for upper molars of males and females for Precontact Agriculture**

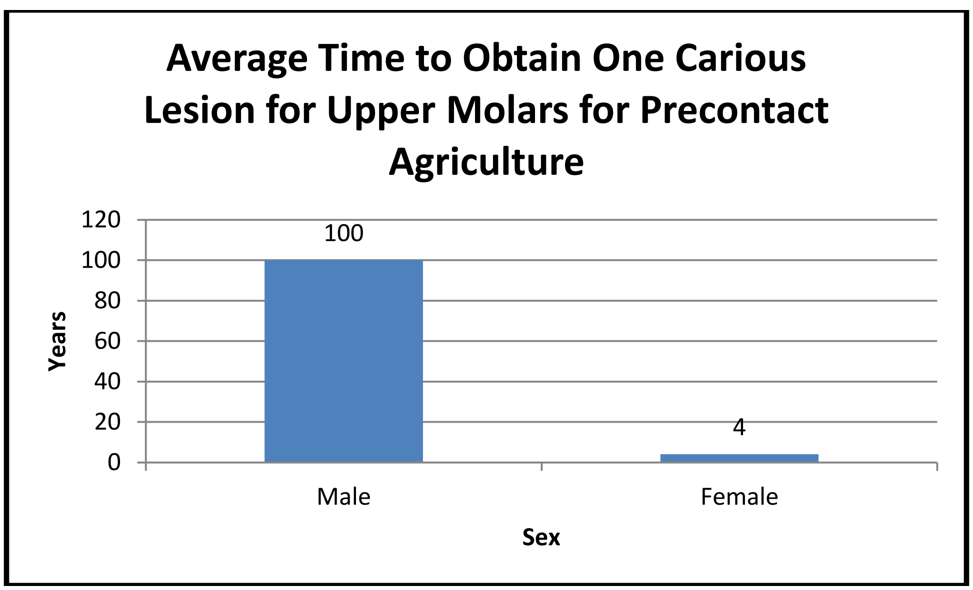
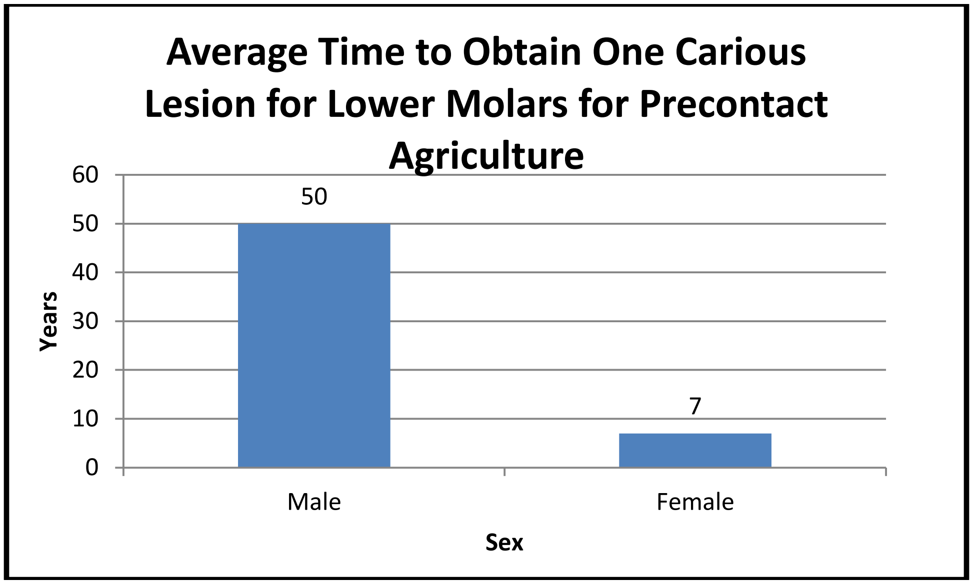


**Figure 6. Average Time to obtain carious lesions for lower molars of males and females for Precontact Agriculture**




**Discussion**

The overall results of this study confirm the hypothesis that change in subsistence base is the main contributing factor to change in the frequency of dental caries and increase overtime, resulting in poorer oral health. The frequency of dental caries increases dramatically after the twelfth century. That is, populations in the Georgia bight at this time began to have an increased consumption of maize, coinciding with an increase in settlement frequency and density along the coast (Anderson and Mainfort, 2002; Hutchinson et al., 1998; Thompson and Turck, 2009). There was never a complete disuse of marine resources, as evident by stable isotope analysis from the work of Larsen and colleagues (Larsen et al., 1992; Larsen et al., 2007), and some areas of the coast were unsuitable for maize agriculture (Reitz, 1988). However, overall, there was a general trend of increased maize consumption during the time coinciding with the increase in the frequency of dental caries for the Precontact Agriculture populations (Larsen, 1982; Larsen et al., 2007; Larsen, 1982).

The results of the regression models also showed that there was a higher rate of dental caries among females as compared to males for the Precontact Agriculture group for both upper molars and lower molars with females exhibiting a much higher rate of dental caries than males. Females could be exhibiting higher rates of dental caries for several reasons. Females might be living longer than males. Since dental caries accumulate over a person's lifetime, the longer a person lives theoretically the more dental caries they will possess when compared to someone who is younger. Also, this may be evidence of sexual division of labor. For example, males may be consuming more meat and fewer carbohydrates, in comparison to females, resulting in less dental caries, while females are consuming more carbohydrates and less meat, in comparison to males, resulting in a higher frequency of dental caries. This would be due to males performing the majority of the hunting while females are performing the majority of the foraging and food preparation (Kelly, 2007). An alternative explanation, suggested by Lukacs, is hormones are playing a role. The hormonal fluctuations experienced by women when they are going through menses, pregnancy, or menopause can have an effect on the saliva of the mouth and therefore the oral ecology of the mouth resulting in an increase of dental caries (Lukacs and Largaespada, 2006). However, the author interprets this higher frequency of dental caries among females as compared to males as a result of above mentioned dietary differences.

This analysis supports a number of previous studies concerning stress and subsistence patterns of populations of the Georgia bight and southeastern United States (Larsen, 1981; Larsen, 1982; Larsen, 1983; Larsen et al., 1991; Larsen et al, 1992; Larsen et al, 2007; Hutchinson et al, 1998). This overarching trend being that as populations continued to grow they became more dependent upon agriculture, specifically maize in the southeastern United States. Once the Europeans established contact with the populations of these areas, the use of maize became even more exacerbated. The result was an overall deterioration of health including a continuing increase of dental caries (Hutchinson et al., 1998; Kelley and Larsen, 1991; Larsen, 1982; Larsen et al., 1992; Larsen et al., 2007).

**Summary and Conclusions**

This study has added to a growing and broader understanding of the effects of shift in subsistence and settlement, by re-examining a data set using a more rigorous statistical analysis. The results confirm the hypothesis and are interpreted as the increase in maize agriculture coinciding with the increase in dental caries among the populations resulting in poorer oral health. These results have helped to support previous findings that along the Georgia bight with the adoption of maize agriculture, around the twelfth century, there were human impacts (Hutchinson et al., 1998; Larsen, 1981; Larsen, 2001; Larsen et al., 1998; Larsen et al., 1992; Larsen et al., 2001; Schoeninger et al., 1990). These impacts were also reflected among the sexes, with females showing a higher rate of dental caries than the males.

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